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(54) **Pulse compression radar**

(57) Radar apparatus comprises a transmitter (2), an antenna (4), and a receiver (7). The transmitted signal is encoded (8), and the same code (76) stored in the receiver (7) is used in the time-compression (by unit 75) of received, digitised IF signals. The receiver periodically adapts itself by processing a test sample (5, 6) of the encoded signal for transmission, adjusting the code in the store (76) accordingly.

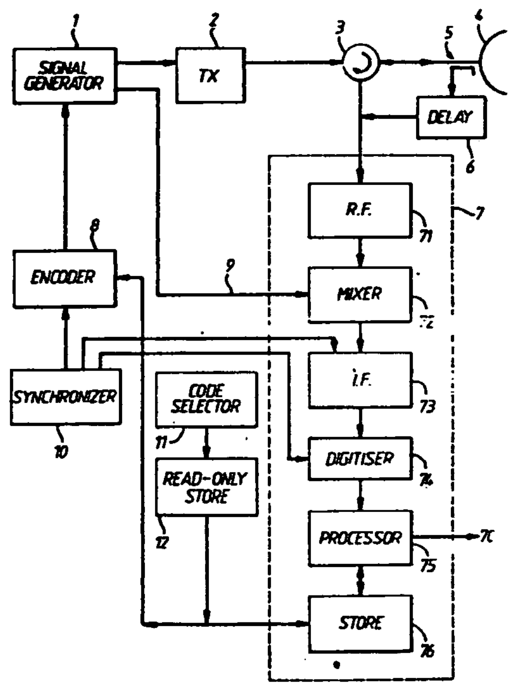

FIG.1.

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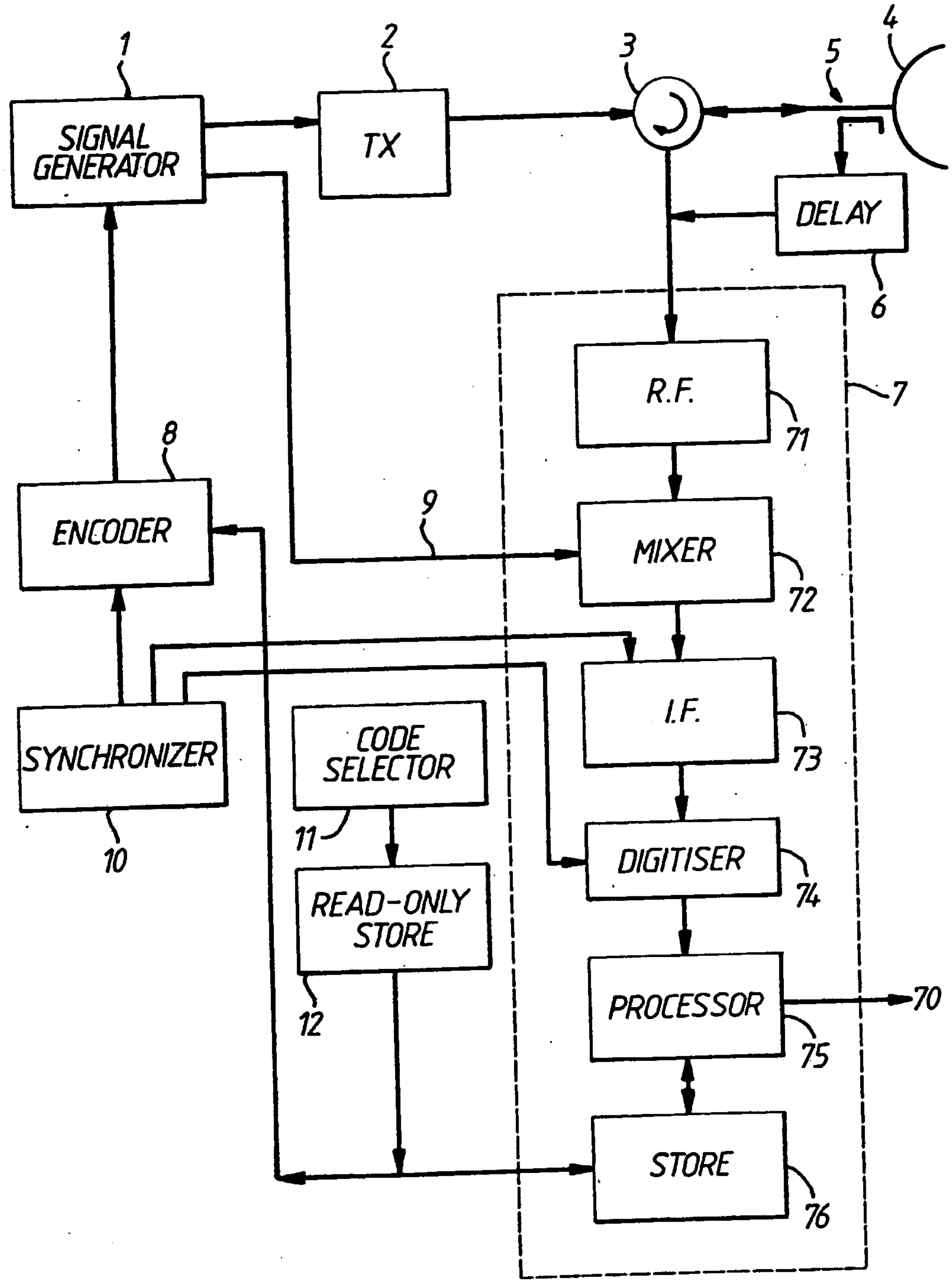

FIG.1.

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PULSE COMPRESSION RADAR

This invention relates to radar apparatus in which the time extent of the transmitted pulses is broadened by encoding the pulse which is transmitted and compressing the received pulses so as to obtain short pulses at times indicative of target range. The compression of the received signals is achieved by correlating the signals with a stored signal which is chosen to compress the modulated transmitted pulses. Such a technique is an example of the use of matched filters. However the compression/expansion functions can be mis-matched to improve time sidelobes.

Pulse compression radar enables a substantial average power output to be maintained even with transmitters of comparatively low peak power output. However, the range resolution depends critically on the efficiency of compression, i.e. on the degree of correlation between the modulation carried by the received signal and the stored signal. Phase and amplitude distortions in the transmitter and receiver paths cause significant time sidelobes in the compressed output which can introduce spurious targets.

It has previously been proposed to provide an adaptive transmitter, which is rendered coherent by feeding back the compressed output after each pulse, and adapting the waveform generator of the transmitter

accordingly. This has the disadvantage that time must be allowed in each pulse repetition interval for the adaptive co-efficient of the waveform generator to be changed; such a radar system cannot respond to close in targets. They also cannot easily correct for amplitude distortions, as the transmitter is run saturated. Further, magnetrons could not be used in such a radar system, since they cannot be made adaptive.

In order to overcome these problems, the invention provides radar apparatus comprising a transmitter connected to provide to an antenna a pulsed signal of which the pulses are encoded by a modulating signal, a receiver comprising a compressor which time-compresses the received signal returned from targets by correlating it with a stored signal similar to the modulating signal, and means for returning to the receiver a test sample of the encoded signal before it reaches the antenna, the receiver comprising adapting means for adjusting the said stored signal, in response to the time-compressed output from the compressor due to the test sample, such as to optimise the time-compression.

By sampling the signal for transmission in this way, and using it to adapt the receiver, phase and amplitude distortions from any part of the transmitter and receiver may be compensated for assuming these distortions are linear, i.e. not power-level dependant. This avoids the need to make adaptations at the pulse repetition

frequency; the adaptation need only be made comparatively infrequently assuming the time constants of the distortions are also infrequent. Thus in radar apparatus embodying the invention there is no minimum range requirement implied by the adaptive compression/expansion system.

Although it is contemplated that the invention is particularly useful in radio frequency radar, the invention could be used in sonar systems, and for the purposes of this specification, the term "radar" is intended to include sonar.

The compressor may comprise a finite impulse response filter whose stored coefficients define the said stored signal. Preferably, however, the compressor comprises digital means for taking the Fourier transform of the received signal and multiplying that with the stored signal in digital form to provide an output representative of the said correlation, and for taking the inverse Fourier transform of the said output to derive the time-compressed output of the compressor. The stored signal will be a conjugated frequency domain reference calculated from the reference signal.

One way in which the invention may be performed will now be described, by way of example only, with reference to the accompanying diagrammatic circuit diagram of radar apparatus.

A microwave waveform generator 1 provides an

encoded, pulsed signal to a radar transmitter up-converter 2 whose output is passed via a duplexer such as a circulator 3 to an antenna 4. The pulse repetition frequency is controlled by the signal generator 1, and the modulating signal, which is applied to each pulse, is determined by an encoder 8, activated by a time and frequency synchroniser 10.

A number of different predetermined codes, stored in a read-only store 12 controlled by a code selector 11, may be used: the code which is selected is written into the encoder 8 from the read-only store 12, and may periodically be substituted for a different code. One example of a suitable code is a chirp, in which, in each rectangular pulse, the frequency of the signal is varied as a linear function of time.

The received signal returned from targets is sent by the circulator 3 to a receiver block 7 which includes digital apparatus for compressing the signal in the time domain to provide an output signal 70 consisting of comparatively narrow pulses containing range information relating to the targets. Within the receiver block 7, an RF receiver 71 passes radio frequency signals to a mixer 72 which mixes those signals with local oscillator signals provided on line 9 from the signal generator 1. An intermediate frequency receiver 73 receives the heterodyned output of the mixer 72 and provides an analogue output to a digitiser 74; the IF receiver 73 and

the digitiser 74 are both synchronised by pules from the time and frequency synchroniser 10. The digitised IF output is provided to a digital processor 75 which is responsible for the time-compression of the received signals.

The digital processor 75 accesses a read-write store 76 containing, in digital form, a reference signal corresponding to the code currently being applied by the encoder 8 to the transmitted signals. Thus the read-only store 12 is connected to supply the selected code to the signal store 76 as well as to the encoder 8.

The digital processor 75 takes the Fourier transform (using fast Fourier transform techniques) of the digitised received signal and the Fourier transform of the stored signal 76, to obtain functions in the frequency domain, instead of the time domain, and multiplies together the two Fourier transforms. The result of this multiplication is then changed back into the time domain by applying an inverse digital Fourier transform. The resulting time-domain signal is representative of the correlation in the time domain between the received signal and the stored signal, and thus represents the compressed output signal required. The digital processor 75 may also be of the form of a finite impulse response filter.

In order to compensate for phase errors in the signal generator 1 and radar transmitter up-converter 2, and in the circulator 3, and the consequential mis-match between

the modulation of the received signal and the stored signal in the store 76, the stored signals in store 76 are periodically corrected. In this way, the receiver block 7 is adaptive. This is achieved by using a coupler 5 to take a test sample of the encoded signal before it reaches the antenna 4, and applying the test sample to the receiver block 7 at a time when it is not processing other received data. The processor 75 responds to the digitised test sample from the digitiser 74 to adjust the stored signal in store 76 such as to approximate more closely the modulation on the test sample. After this correction has been made to this reference signal in the signal store 76, subsequent operations of the receiver block 7 will compress the received signals more efficiently, since there will be a greater correlation between the modulation of the received pulses and the stored reference signal.

A delay unit 6 is provided in the path between the coupler 5 and the receiver block 7 so that the test sample arrives at a delay so that the true signal is separated in time from any possible interference from the transmitter. The radar may be calibrated using a known target at far range.

A control system (not shown) determines the frequency at which a test sample is taken by the coupler 5 and the reference signal in store 76 is corrected; this frequency will usually be substantially less than the pulse repetition frequency of the radar system. For example,

the reference signal may be corrected once in every 10 radar pulses.

An alternative to the digital processing described above would be to provide a finite impulse response filter for the compressing of the received signals. The signal store 76 would then store the coefficients for the stages of the filter, which may, for example, be 128 in number. Data from the intermediate frequency receiver 73 would be fed to the filter, for example at a rate of 6 MHz, which would correlate the data with the stored coefficients by performing complex number multiplications at a rate of the order of 1000 million per second. The output of the filter would consist of pulses in the time domain constituting the compressed output signal 70. During a test cycle, in which a test sample is fed to the receiver block 7, the correlated output 70 would be compared by data processing means with the theoretical optimum waveform, for example a narrow rectangular pulse, and the stored co-efficients corrected in accordance with the comparison such as to approximate more closely the theoretical waveform in subsequent correlations.

CLAIMS

1. Radar apparatus comprising a transmitter connected to provide to an antenna a pulsed signal of which the pulses are encoded by a modulating signal, a receiver comprising a compressor which time-compresses the received signal returned from targets by correlating or convolving it with a stored signal similar to the modulating signal, and means for returning to the receiver a test sample of the encoded signal before it reaches the antenna, the receiver comprising adapting means for adjusting the said stored signal such as to approximate more closely the modulation on the test sample and thus to optimise the time-compression.

2. Radar apparatus according to claim 1, wherein the compressor comprises a finite impulse response filter whose stored coefficients define the said stored signal.

3. Radar apparatus according to claim 1, wherein the compressor comprises digital means for taking the Fourier transform of the received signal and multiplying that with the stored signal in digital form to provide an output representative of the said correlation, and for taking the inverse Fourier transform of the said output to derive the time-compressed output of the compressor.

4. Radar apparatus according to any preceding claim, comprising an antenna and a duplexer interconnecting the transmitter, the receiver and the antenna, wherein the returning means comprises a coupler for obtaining the test

sample from a line interconnecting the duplexer and the antenna.

5. Radar apparatus according to Claim 4, wherin the duplexer comprises a circulator.

6. Radar apparatus according to any preceding claim, wherein the returning means comprises delay means for delaying the test sample before it reaches the receiver by a controlled interval.

7. Radar apparatus according to any preceding claim, comprising means for controlling the receiver to receive and process a test sample only once in a plurality of pulse repetition intervals of the radar apparatus.

8. Radar apparatus substantially as described herein with reference to the drawing.

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